

SAMS Acceleration Measurements on Mir from June to November 1995

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Abstract

The NASA Microgravity Science and Applications Division (MSAD) sponsors science experiments on a variety of microgravity carriers, including sounding rockets, drop towers, parabolic aircraft, and Orbiter missions. The MSAD sponsors the Space Acceleration Measurement System (SAMS) to support microgravity science experiments with acceleration measurements to characterize the microgravity environment to which the experiments were exposed. The Principal Investigator Microgravity Services project at the NASA Lewis Research Center supports principal investigators of microgravity experiments as they evaluate the effects of varying acceleration levels on their experiments.

In 1993, a cooperative effort was started between the United States and Russia involving science utilization of the Russian Mir space station by scientists from the United States and Russia. MSAD is currently sponsoring science experiments participating in the Shuttle-Mir Science Program in cooperation with the Russians on the Mir space station. Included in the complement of MSAD experiments and equipment is a SAMS unit. In a manner similar to Orbiter mission support, the SAMS unit supports science experiments from the U.S. and Russia by measuring the microgravity environment during experiment operations.

The initial SAMS supported experiment was a Protein Crystal Growth (PCG) experiment from June to November 1995. SAMS data were obtained during the PCG operations on Mir in accordance with the PCG Principal Investigator's requirements. This report presents an overview of the SAMS data recorded to support this PCG experiment.

The report contains plots of the SAMS 100 Hz sensor head data as an overview of the microgravity environment, including the STS-74 Shuttle-Mir docking.

Acronyms and Abbreviations

DMT	Decreed Moscow Time
ECK	inertial coordinate system (Russian acronym)
ftp	file transfer protocol
Hz	Hertz
LeRC	NASA Lewis Research Center
MLT	Moscow local time
MSAD	Microgravity Science and Applications Division
PCG	Protein Crystal Growth experiment
PCSA	principal component spectral analysis
PGO	(Russian acronym)
PIMS	Principal Investigator Microgravity Services
PNO	(Russian acronym)
PSC	principal spectral component
PSD	power spectral density
PSO	Mir module transfer/docking compartment (Russian acronym)
RMS	root mean square
rpm	revolutions per minute
SAMS	Space Acceleration Measurement System
SMSP	Shuttle-Mir Science Program
TSH	triaxial sensor head
WWW	world wide web

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1. Introduction and Purpose

The NASA Microgravity Science and Applications Division (MSAD) sponsors science experiments on a variety of microgravity carriers, including sounding rockets, drop towers, parabolic aircraft, and Orbiter missions. The MSAD sponsors the Space Acceleration Measurement System (SAMS) to support microgravity science experiments with acceleration measurements to characterize the microgravity environment to which the experiments were exposed. Between June 1991 and March 1996, the SAMS project participated in fourteen NASA Orbiter missions with six SAMS flight units. The Principal Investigator Microgravity Services (PIMS) project at the NASA Lewis Research Center (LeRC) supports principal investigators of microgravity experiments as they evaluate the effects of varying acceleration levels on their experiments.

In 1993, a cooperative effort was started between the United States and Russia involving science utilization of the Russian Mir space station by scientists from the United States and Russia. MSAD is currently sponsoring science experiments participating in the Shuttle-Mir Science Program (SMSP) in cooperation with the Russians on the Mir space station. Included in the complement of MSAD experiments and equipment is a SAMS unit.

On 25 August 1994, a SAMS unit was launched on a Russian Progress vehicle to the Mir space station. In a manner similar to Orbiter mission support, the SAMS unit supported science experiments from the U.S. and Russia by measuring the microgravity environment during experiment operations.

The initial SAMS supported experiment was a Protein Crystal Growth (PCG) experiment from June to November 1995. SAMS data were obtained during the PCG operations on Mir in accordance with the PCG Principal Investigator's requirements. This report presents an overview of the SAMS data recorded to support this PCG experiment.

Appendix A describes the procedures to access additional information about SAMS and PIMS utilizing the internet. Appendices B and C provide plots of the SAMS 100 Hz sensor head data as an overview of the microgravity environment. Appendices D and E provide plots of the SAMS 100 Hz sensor head data as an overview of the microgravity environment during the STS-74 Shuttle-Mir docking. Appendix F contains a user comment sheet. Users are encouraged to complete this form and return it to the authors.

2. Data Acquisition and Processing

The first PCG Dewar apparatus was installed on Mir during the STS-71 Shuttle mission to Mir (27 June to 7 July 1995). The PCG Dewar began autonomous operations approximately five days after installation in Mir. The SAMS unit recorded microgravity acceleration periodically to support the characterization of the PCG microgravity environment. A second PCG Dewar apparatus was installed on Mir in November 1995 (during the STS-74 mission). The first PCG Dewar was recovered by the PI when it returned on the STS-74 Orbiter, after its 125 days on-board Mir.

Five SAMS optical disks were returned to Earth by Russian cosmonauts in September, 1995 and six SAMS optical disks were returned to Earth by STS-74 in November 1995. These data were processed by the SAMS project and made available to users on a NASA LeRC file server. See Appendix A for instructions on accessing these data.

The SAMS data from Mir were examined by PIMS to determine characteristics of the data to support PCG and to further characterize the Mir microgravity environment.

Prior reports [1,2] summarize the characteristics of the SAMS data from the initial SAMS operations on Mir in 1994.

3. Mission Configuration

3.1 Mir Configuration

The Mir space station was launched in 1984 as a base module and has been expanded since that time to include five modules in 1996. The overall space complex mass exceeds 90,700 kilograms. The length along the longitudinal axis is about 33 meters and the length along the lateral axis is about 27 meters.

Figure 1 shows a typical configuration of the Mir space station. The five major components are the Mir core module, the Kvant-1 astrophysics module, the Kvant-2 scientific and airlock module, the Kristall technological module, and the Spektr laboratory module. The Mir modules are occasionally reoriented for mission activities such as vehicle docking events.

The Spektr module was added to Mir in May 1995, and the Priroda module was added in April 1996.

3.2 Mir Coordinate System

The Mir basic coordinate system is the base module coordinate system, figure 1.

3.3 Mir Attitudes

The orientation attitudes of Mir during the June to November 1995 time period are not known at the present time.

The Mir space station periodically reestablishes its attitude. This is accomplished by turning station-keeping gyrodynes off, and using thrusters to establish the new attitude. When the new attitude is established, the gyrodynes are turned on again. The exact meaning of gyrodyne "turn off" is not clear.

4. Triaxial Sensor Head Orientation and Location

A SAMS triaxial sensor head (TSH) is mounted to a structure or an experiment in a predetermined manner. The orientation of the TSH axes relative to the vehicle is measured and recorded for later use in understanding the acceleration data. Using this information, the

measured acceleration levels may be transformed to other orientations, such as an experiment-based coordinate system or the Mir coordinate system. During the timeframe of data for this report, the SAMS TSHs were mounted near the PCG apparatus in the Kvant-1 module. Table 1 list the location and orientation of the two active SAMS TSH's during these operations. During the Shuttle docking, the SAMS sensors were mounted in the Kristall module.

5. Protein Crystal Growth Experiment Location

The PCG apparatus was located in Kvant-1.

6. Mission Activities

An English version of the ground controller's logbook [3] has been examined for major activities during this time period. The logbook does not give much detail concerning the operation of Mir equipment which may cause disturbances to the microgravity environment. Activities which occurred during the span of SAMS recorded data are listed and/or described below. Some of these activities are described in later sections.

The normal awake period (figure 2) for the Mir crew appears to be from 08:00 until 23:00. Exercise is conducted on a daily basis and the crew members have 3 meals per day. Major activities derived from the controller's logbook are summarized in figure 3 along with a graphical view of the SAMS data recording.

The times shown are in hour:minute:second format and are based on DMT (Decreed Moscow Time). In this report, MLT (Moscow Local Time) has been used interchangeably with DMT, but DMT is the proper system to use for this data.

Day 079 (20 March 1995)

The SAMS was operated for a calibration cycle and for crew familiarization and training.

Day 087 (28 March 1995)

The SAMS was operated for a calibration cycle and for crew familiarization and training.

Day 197 - 198 (16 - 17 July 1995)

There appears to be a relocation of the Kristall module during this period. When moving a module, there is much crew activity in order to disconnect, move, and reconnect utility lines that cross-through the air locks between modules. Hatches are opened and closed, and leak checks are performed.

Crew exercise was performed during this period.

Day 216 - 217 (4 - 5 August 1995)

This was a quiet time with crew rest, medical exams, and personal time.

Crew exercise was performed during this period.

Day 237 - 239 (25 - 27 August 1995)

Crew exercise was performed during this period.

Day 248 - 250 (5 - 7 September 1995)

A Soyuz capsule (TM22) with new crew members docked with Mir during this time period. This type of event includes mechanical latching, hatches opening, and logistics transfers from the Soyuz vehicle.

Crew exercise was performed during this period.

Day 319 - 320 (15 - 16 November 1994)

The Orbiter docked with Mir during the STS-74 mission in this time period. This type of event involves mechanical latching, hatches opening, and logistics transfers between Mir and the Orbiter.

Crew exercise was performed during this period.

7. Analysis Techniques

The SAMS data were examined using acceleration versus time, power spectral density (PSD), principal component spectral analysis (PCSA), and spectrogram techniques. Each of these techniques highlights different factors contained in the data. The principal component spectral analysis (PCSA) technique was used to examine the SAMS data in the frequency domain. This technique calculates a power spectral density (PSD) plot of a specified length of time, then determines local peaks within the PSD data. The local peak algorithm is described in reference 4. Consecutive PSDs from a 8.74 minute time span of data were processed and combined into the single PCSA plot.

The PCSA plot has characteristics which illustrate additional information compared with a standard PSD plot. For additional information on this technique, see reference [2].

8. Mir Structural Modes

The PCSA plot in figure 4 illustrates the structural modes of the Mir space station during the time in which these data were gathered (September 1995).

The PSD plot shown in figure 5 is a combination of 1406 successive PSD analysis, each of which represent 20.48 seconds (Welch's method). The data contained in each of the discrete frequency bins were averaged among all of the PSD plots. This illustrates that the structural frequencies are present in the data for nearly all the time in which data were recorded. The structural mode frequencies appear to be 0.7, 1.1, 1.4, and 1.9 Hz. With the addition of the Spektr module, these frequencies are different from those reported earlier from SAMS measurements on Mir in 1994 [1,2]. The approximate range of frequencies are still comparable with those frequencies reported in the literature [5] from earlier measurements by Center National d'Etudes Spatiales (CNES).

9. Shuttle - Mir docking

The shuttle mission STS-74 was launched at 07:30:43 AM Eastern Standard Time on 12 November 1995 with docking reported at shuttle mission elapsed time (MET) of 002/17:56:57, this corresponds to a Moscow local time of 15 November 1995 at 09:27:40.

The STS-74 docking is apparently seen in the SAMS data at about MLT 319/08:42, according to the SAMS internal clock. This is seen as an impulsive event in figure 6 at that time. The first action of the Orbiter docking to Mir is a "soft dock" before the final mate. At first contact, three latches close and hold the two vehicles together. The Orbiter is put into a free drift mode upon initial contact with Mir. Over the next several minutes electric actuators pull the docking interfaces together (about 0.6 m) and 12 hooks are latched to ensure an airtight seal. It appears that the actions of these (hooks making the hard mechanical connection) are seen in the SAMS data at MLT 319/08:47 as a second impulsive event in figure 6 at that time. After the first contact, a faint 17 Hz signal is present in the SAMS data and, after the hard mechanical connection, a strong 17 Hz signal can be seen in the color spectrogram of figure 6 [6]. The Orbiter's Ku-band antenna generates a well-defined 17 Hz signal. It is speculated that the appearance of this signal on Mir marks the contact time of the two vehicles.

A PSD of the Mir microgravity environment before and after the Orbiter docked to Mir are shown in figures 7 and 8, respectively. The most noticeable differences between these PSD plots are the 17 Hz peak from the Ku-band antenna and magnitude changes in frequencies less than 10 Hz (due to structural mode differences).

The difference between the time cited for the Shuttle-Mir docking and the apparent time of the docking is attributed to inaccuracies in recording the power-on time of the SAMS unit on-board Mir prior to the docking. Because the Mir Integration Payload System (MIPS) time synchronization signal was not available at power-up time, the SAMS data time assignment was performed using crew notations as a reference. This anomaly is being investigated.

10. Sensor head installation

It appears that for a short period of time, the sensor head A was not securely fastened to the Mir structure. This is seen at MLT 216/18:55 until MLT 216/19:05 in the data plots of Appendix C. The sensor head was lightly attached between MLT 216/18:55 and MLT 216/19:05, as is evidenced by the strong traces at under 5 Hz, and the faint traces seen around 40 and 80 Hz. The low frequency traces appear to be structural mode disturbances which would be expected, even if the sensor head was lightly attached to structure.

It appears that the SAMS unit was being set-up for operations and the unit was turned on and data was recorded before the sensor head was firmly attached. It appears that the sensor head was attached sometime between MLT 216/19:05 and MLT 216/19:10.

11. Equipment Operation

11.1. Gyrodynes

The nominal speed of the Mir gyrodynes is 10,000 revolutions per minute (rpm) which corresponds to a vibrational frequency of 166.67 Hz. Because the gyrodynes are used for attitude control, speed changes are expected as energy is absorbed and released by the gyrodyne. Each of the major modules of the Mir space station has six gyrodynes for attitude control [7].

Some of the gyrodynes were apparently brought to a stop during the time of SAMS data recording. At MLT 249/07:05 in figure 9, and in the data plots of Appendix C, a trace begins a linear decrease from around 166 Hz. Shortly after this begins, four other traces begin similar decreases in frequency and all continue toward 0 Hz at about MLT 249/20:10.

11.2. Periodic equipment operation

Figure 6 also shows a period of time when some equipment was periodically turning on and off during most of the time of SAMS data recording, an example of which may be seen in the Appendix C spectrograms at MLT 217/04:00. This characteristic was apparent throughout these SAMS data except for days 238 and 239. The cause of this disturbance is unknown at the present time, but is being investigated.

11.3. Water Pump

The 24 Hz vibration from the water pump which was seen in previous accelerometer data [1] was not apparent during the times of this data set.

12. Summary

This report presents the initial examination of the SAMS data acquired on the Mir space station from June to November 1995.

The SAMS unit on-board Mir was installed to support the U.S. PCG experiment flown on Mir under the SMSP. The SAMS TSHs were mounted near the PCG apparatus and recorded data during the times specified by the PCG PI.

A summary of the vector magnitude RMS and average accelerations for the entire data set was produced for the SAMS 100 Hz TSH. Spectrograms were also produced to give a frequency domain summary for the entire mission. These plots are presented in the Appendices. Some characteristics of the SAMS data are outlined in relation to known activities occurring on Mir at times for which data were recorded.

Future work will continue in order to correlate activities and operations with the microgravity environment, and to compare the Mir microgravity environment with that of the NASA Orbiters. As additional data is acquired from SAMS operations on Mir, further analyses will be performed.

13. References

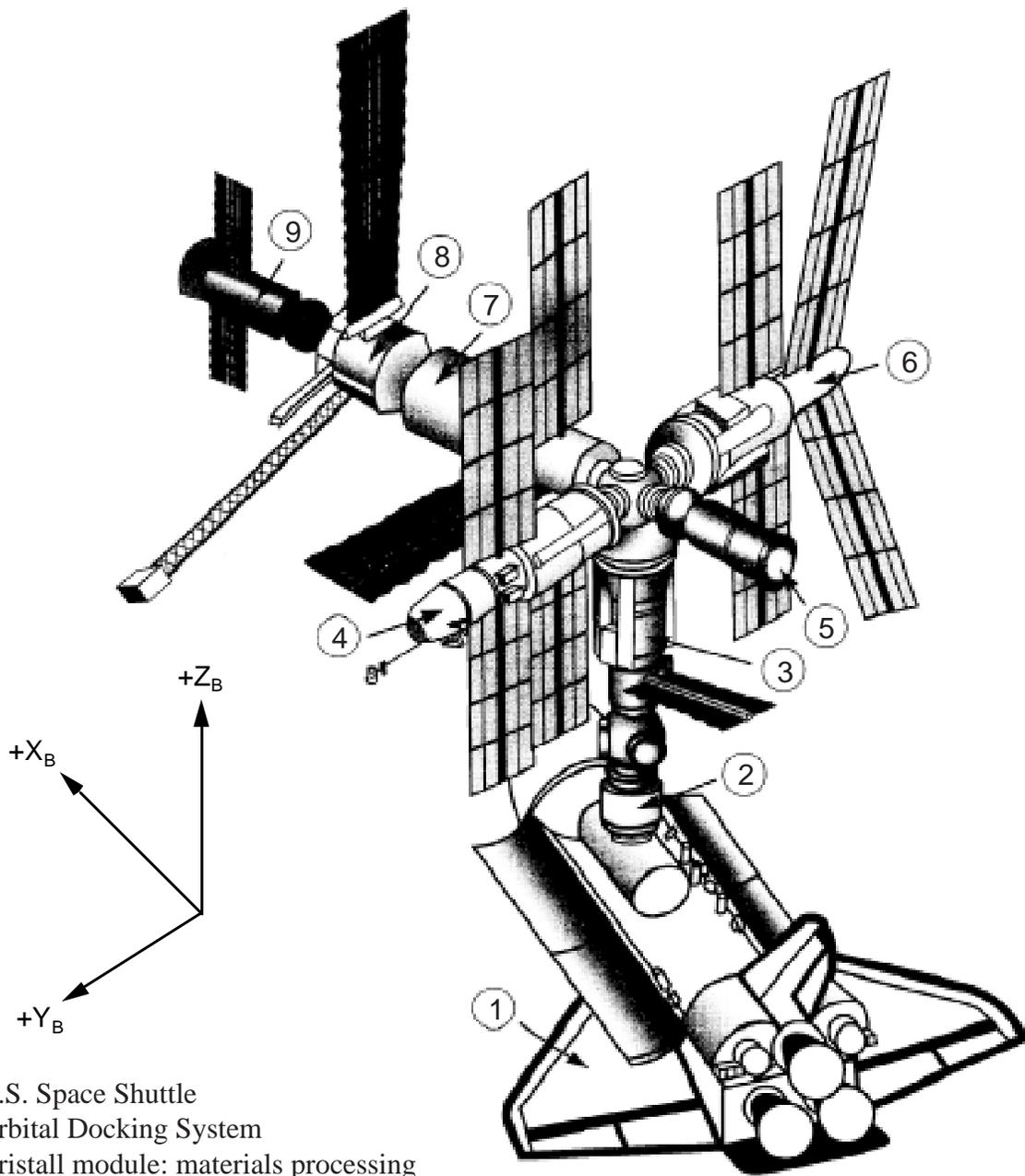
- [1] DeLombard, R. and M. J. B. Rogers: Quick Look Report of Acceleration Measurements on Mir Space Station during Mir-16. TM-106835, 1995.
- [2] DeLombard, R., S. B. Ryabukha, M. Moskowitz, K. Hrovat: Further Analysis of the Microgravity Environment on Mir Space Station during Mir-16. TM-107239, June 1996.
- [3] English translation of The Russian Ground Controllers' logbooks (unpublished)
- [4] "Osprey" software package developed by David K. Mellinger. Bioacoustics Research Program Laboratory of Ornithology Cornell University
- [5] Granier, J.-P., P. Faucher, S. Riaboukha: Mir Microgravity Environment, "microaccelerometre" Experiment. 24th International Conference on Environmental Sytems, Friedrichshafen, Germany, June 20-23, 1994.
- [6] Informal conversation with James D. Halsell, NASA Johnson Space Center
- [7] Bockman, M. W., S. Kelly, et al. (1994). A Russian Space Station: The Mir Complex. Houston, Texas, NASA Johnson Space Center. Document TD501

Table 1. SAMS TSH Orientation in Kvant-1 module.

TSH	Location	TSH Axis	Mir Axis
A	Panel 210	X_h	X_B
		Y_h	$-Y_B$
		Z_h	$-Z_B$
B	Panel 414	X_h	X_B
		Y_h	Y_B
		Z_h	Z_B

Table 2. Mir Activities

Start time	End time	Activity
079/12:44	079/13:10	SAMS data recorded interval
087/21:14	098/22:15	SAMS data recorded interval
197/20:31	198/21:00	SAMS data recorded interval
198/00:30	198/04:15	Kristall module re-docking
198/18:00	198/19:00	Exercise, treadmill and ergometer
216/13:00	216/14:00	Exercise, active rest (?)
216/16:00	216/18:00	Time synchronization, MIPS-1 and SAMS, SAMS calibration, CNES microaccelerometer preparations
216/18:55	217/06:30	SAMS data recorded interval
217/18:20	217/19:20	Exercise, treadmill and ergometer
237/13:00	237/14:00	Exercise, treadmill and ergometer
237/18:30	237/19:10	SAMS operation
237/18:45	239/22:00	SAMS data recorded interval
237/19:10	237/20:10	Exercise, treadmill and ergometer
238/13:30	238/14:20	Exercise, treadmill and ergometer
238/18:10	238/19:10	Exercise, treadmill and ergometer
239/12:10	239/13:20	Exercise, treadmill and ergometer
239/18:40	239/19:40	Exercise, treadmill and ergometer
248/10:00	248/10:30	SAMS & Dewar operations
248/11:07	250/10:00	SAMS data recorded interval
248/12:00	248/13:40	Soyuz docking
248/18:20	248/19:20	Exercise, treadmill and ergometer
249/12:00	249/13:00	Exercise, treadmill and ergometer
249/19:00	249/20:00	Exercise, treadmill and ergometer
250/13:20	250/14:20	Exercise, treadmill and ergometer
250/18:30	250/19:30	Exercise, treadmill and ergometer
319/08:00	319/08:10	SAMS Activation
319/08:30	319/08:35	Docking with STS-74 (time uncertain)
319/09:50	319/11:20	Post-docking leak check
319/17:10	319/17:30	Shuttle in attitude control
319/18:10	319/19:10	Exercise
319/23:20	319/23:40	Shuttle in attitude control
320/08:20	320/08:40	Structural dynamics test
320/09:50	320/10:10	Mir in attitude control
320/11:45	320/12:10	Shuttle in attitude control
320/16:45	320/17:15	Shuttle in attitude control



- 1) U.S. Space Shuttle
- 2) Orbital Docking System
- 3) Kristall module: materials processing
- 4) Kvant II module: scientific
- 5) Soyuz transport vehicle
- 6) Spektr module: geophysical sciences
- 7) Core module: habitation, power, life support
- 8) Kvant module: astrophysics
- 9) Progress vehicle

Figure 1. Typical Mir configuration with docked Orbiter during late 1995.

Typical Day on Mir

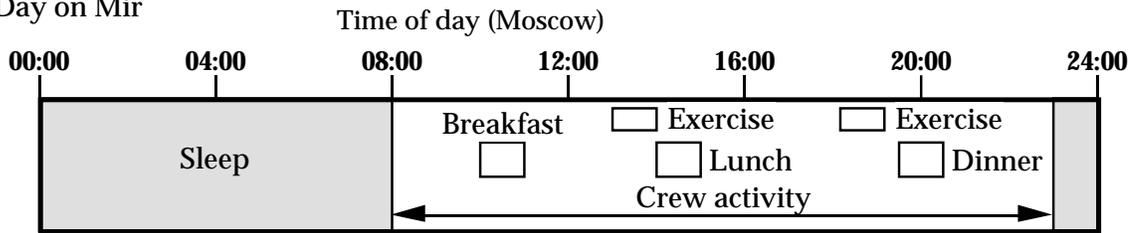


Figure 2. Normal Mir daily activities in 1995.

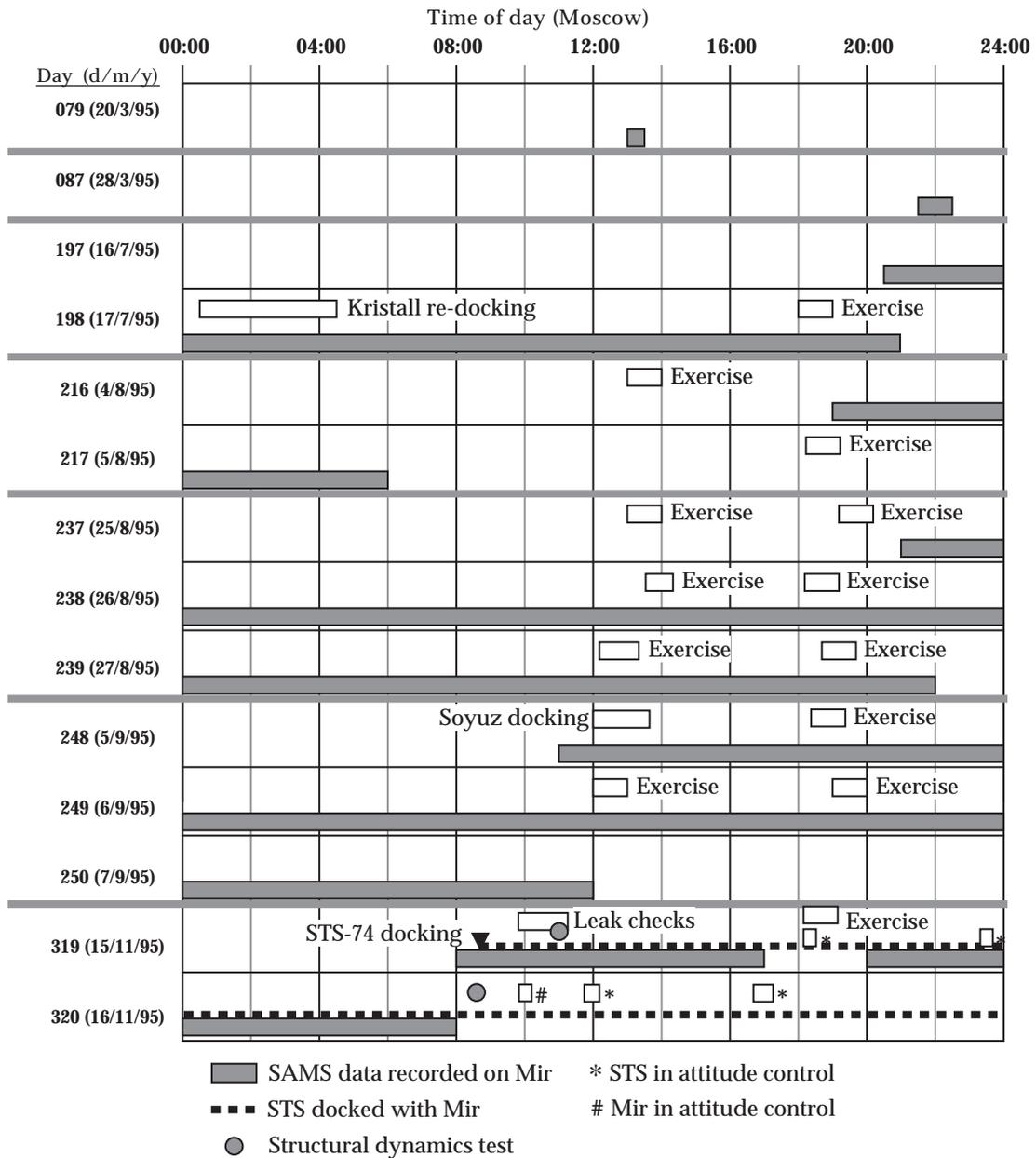


Figure 3. SAMS recording times during 1995 with some Mir activities.

MIR-2, TSH-A: MLT 248/16:00 – 249/16:00, MLT 250/00:00 – 250/10:10

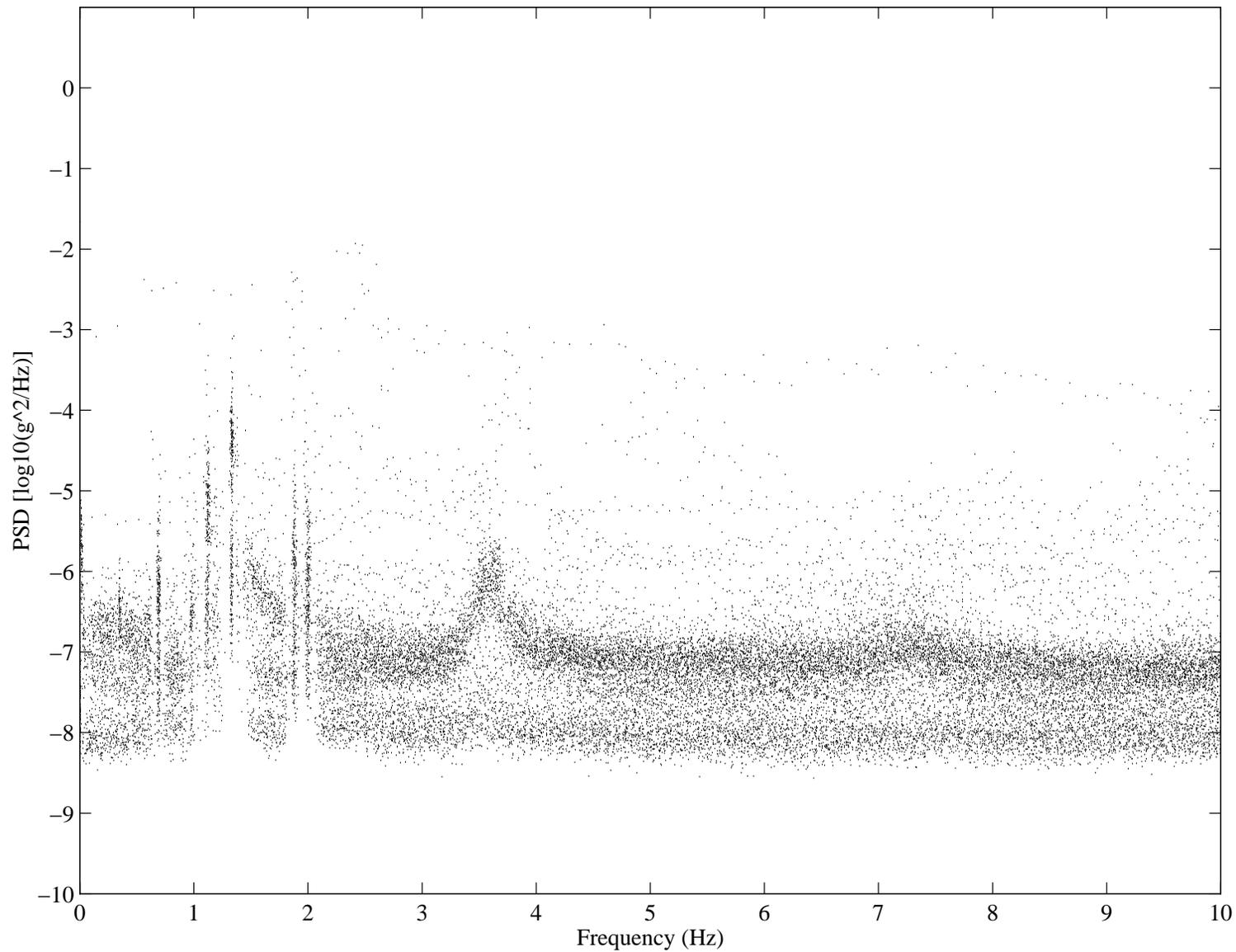


Figure 4. Principal Component Spectral Analysis plot of SAMS Head A data starting at MLT 248/16:00 and 250/00:00.

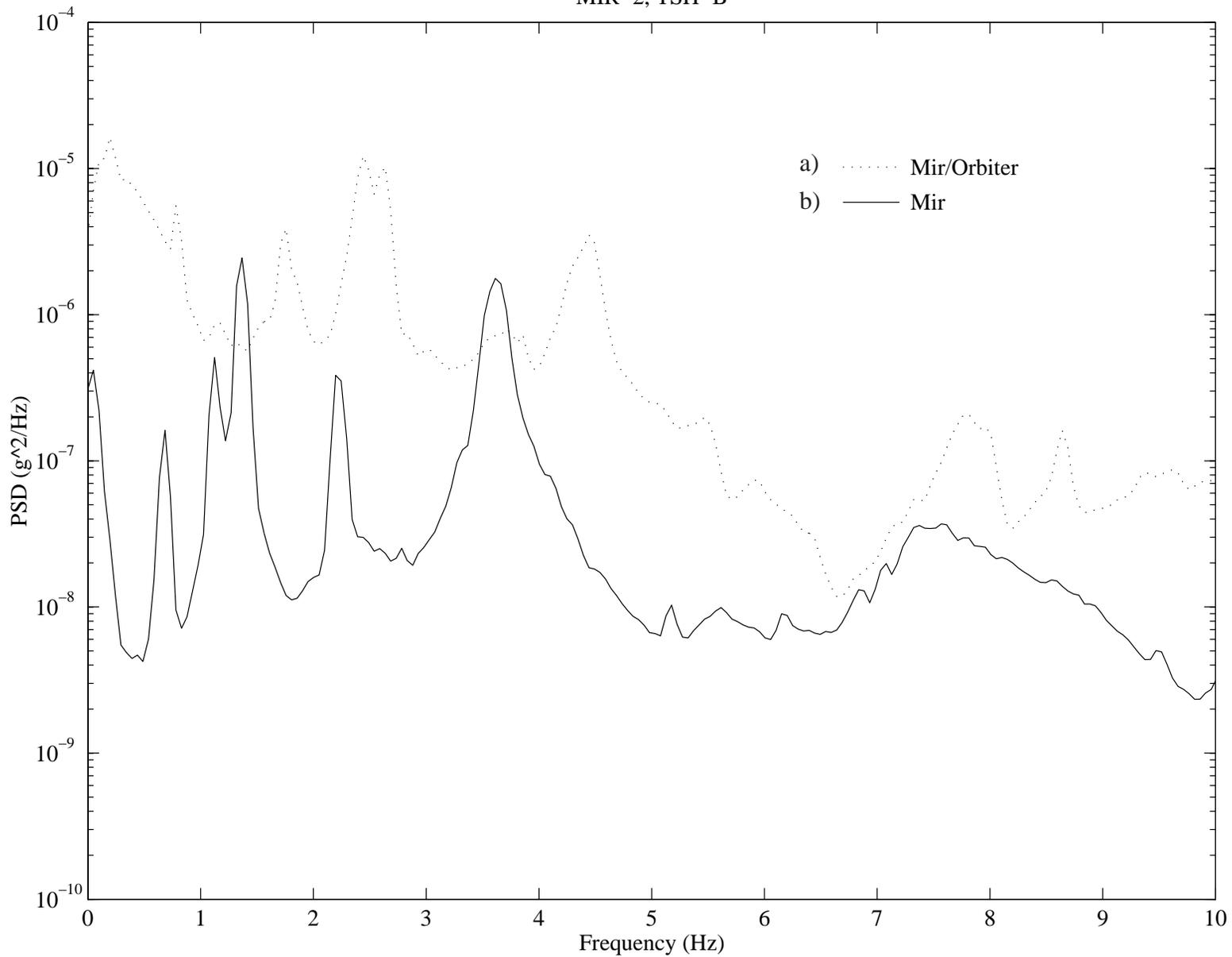


Figure 5. Power Spectral Density plots of SAMS Head B data, a)with Orbiter docked to Mir, b)Mir alone.

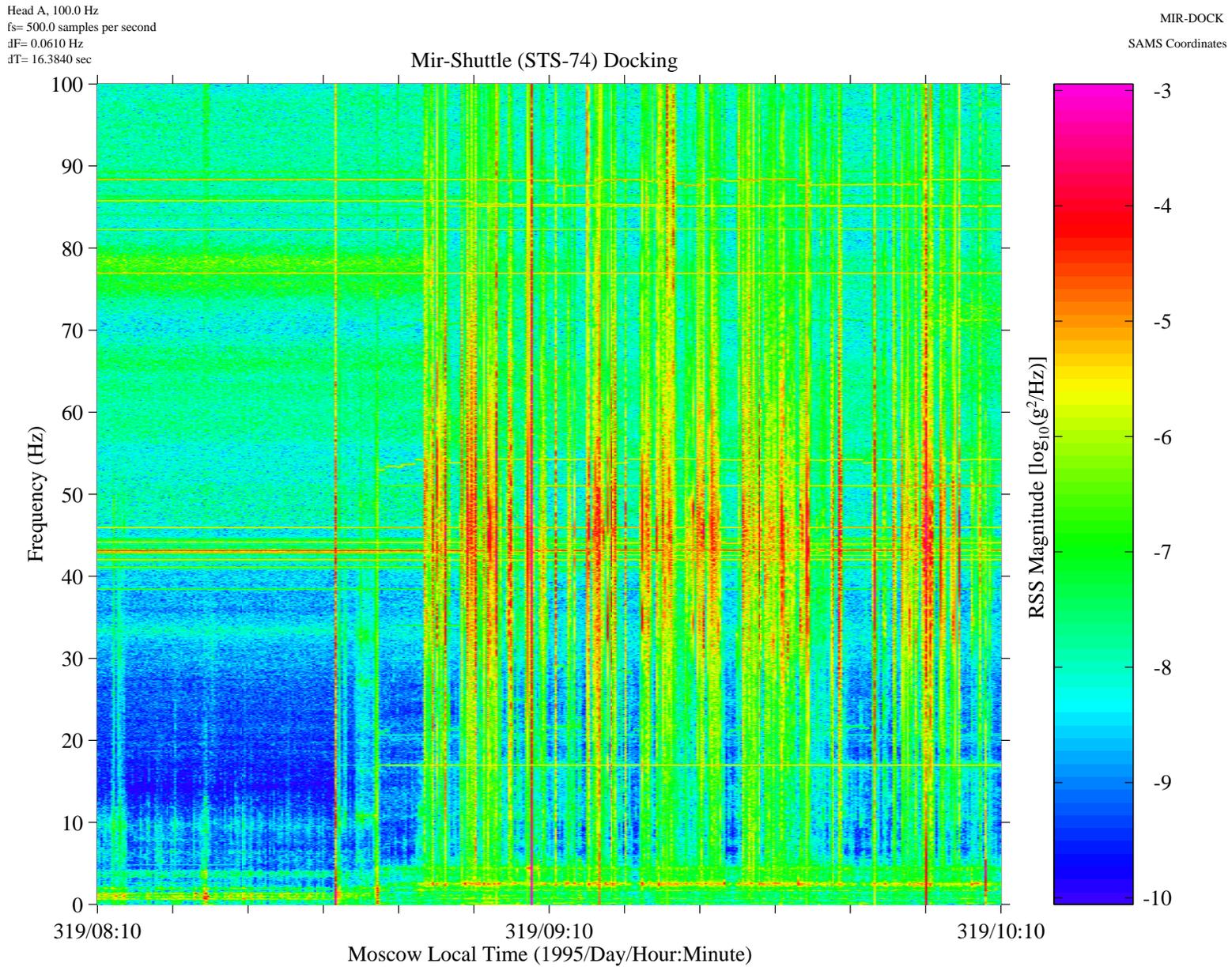


Figure 6. SAMS Head A data starting at MLT 319/08:10.

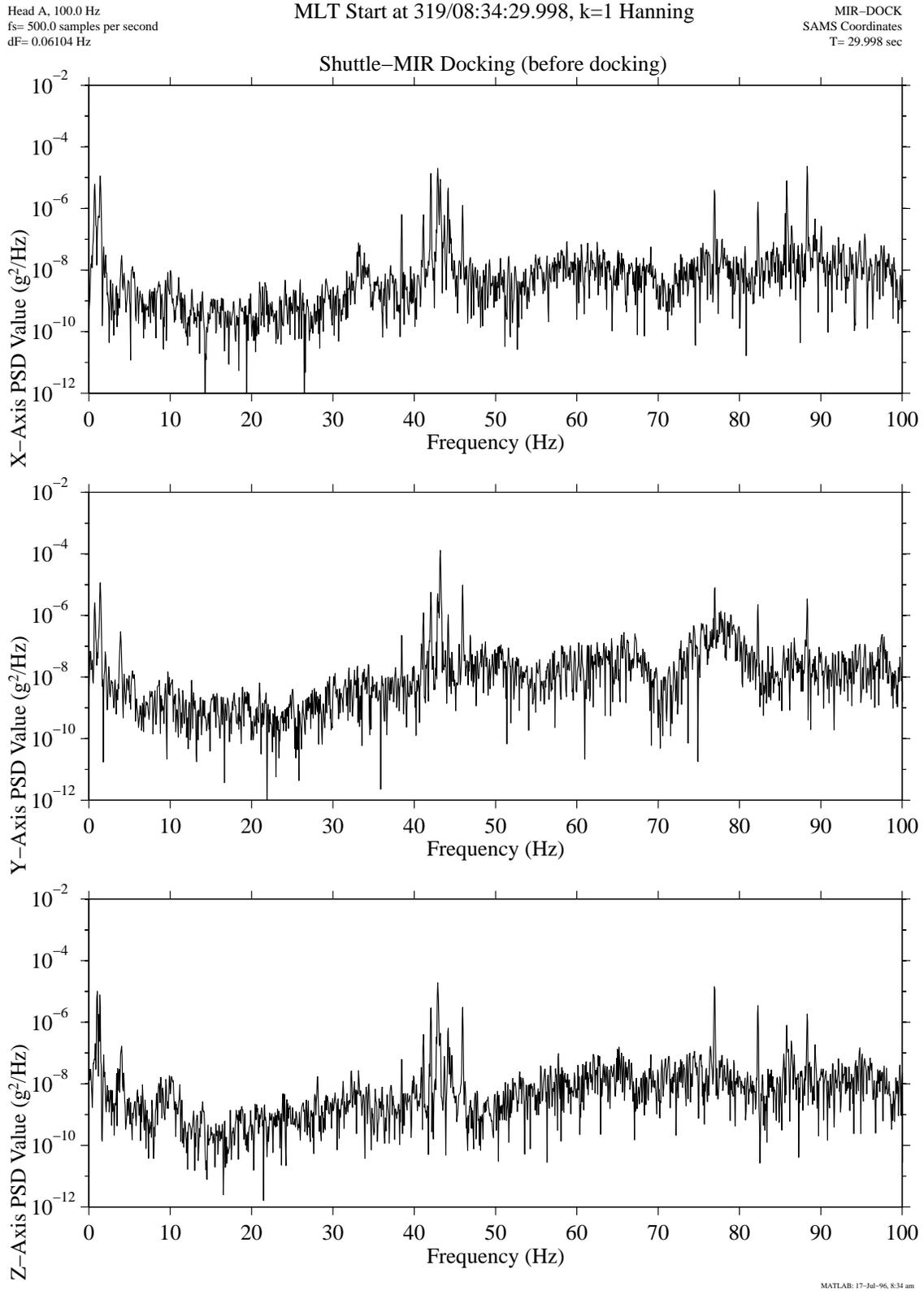


Figure 7. Mir microgravity environment before Orbiter docking.

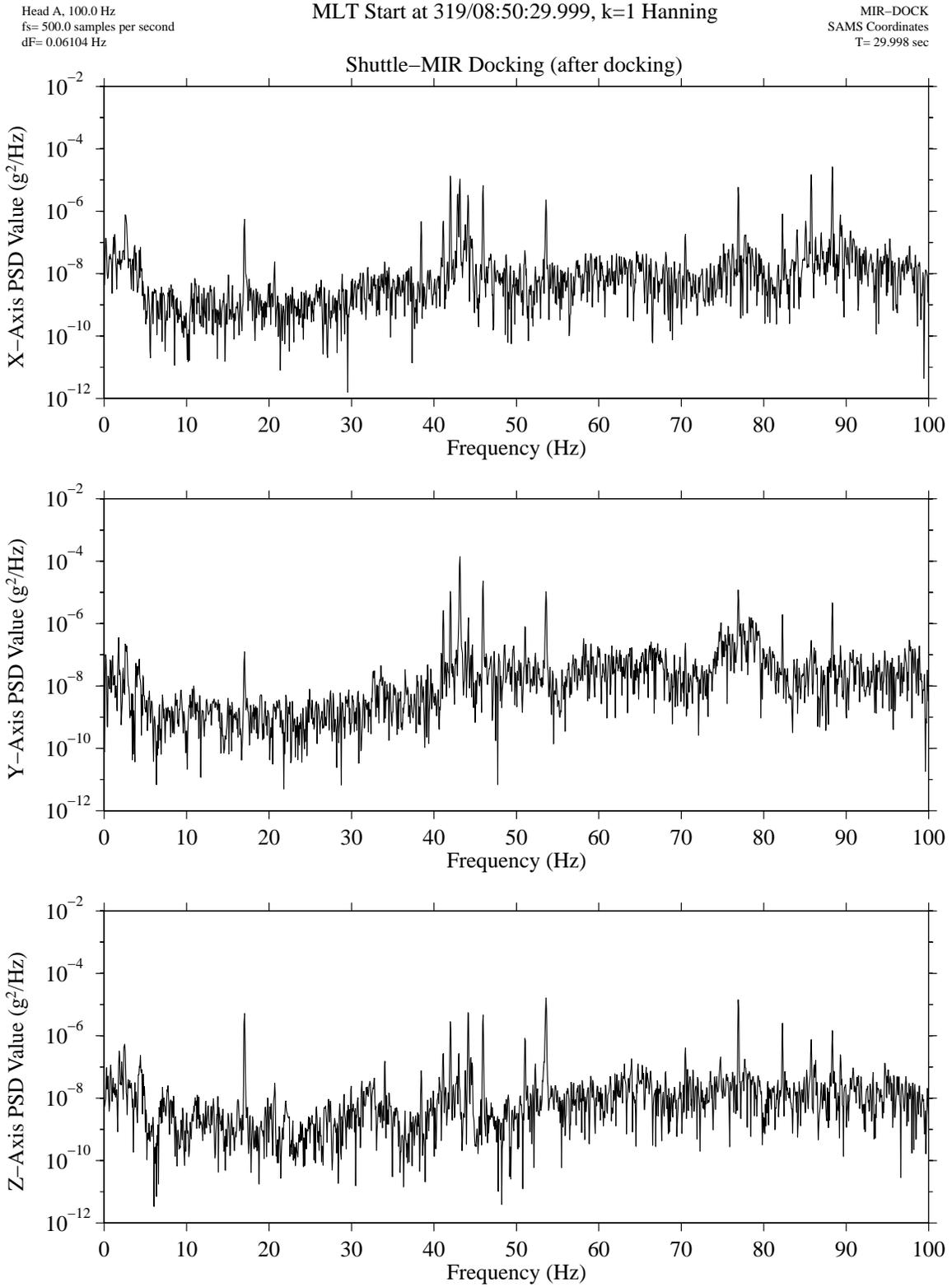


Figure 8. Mir microgravity environment with Orbiter docked.

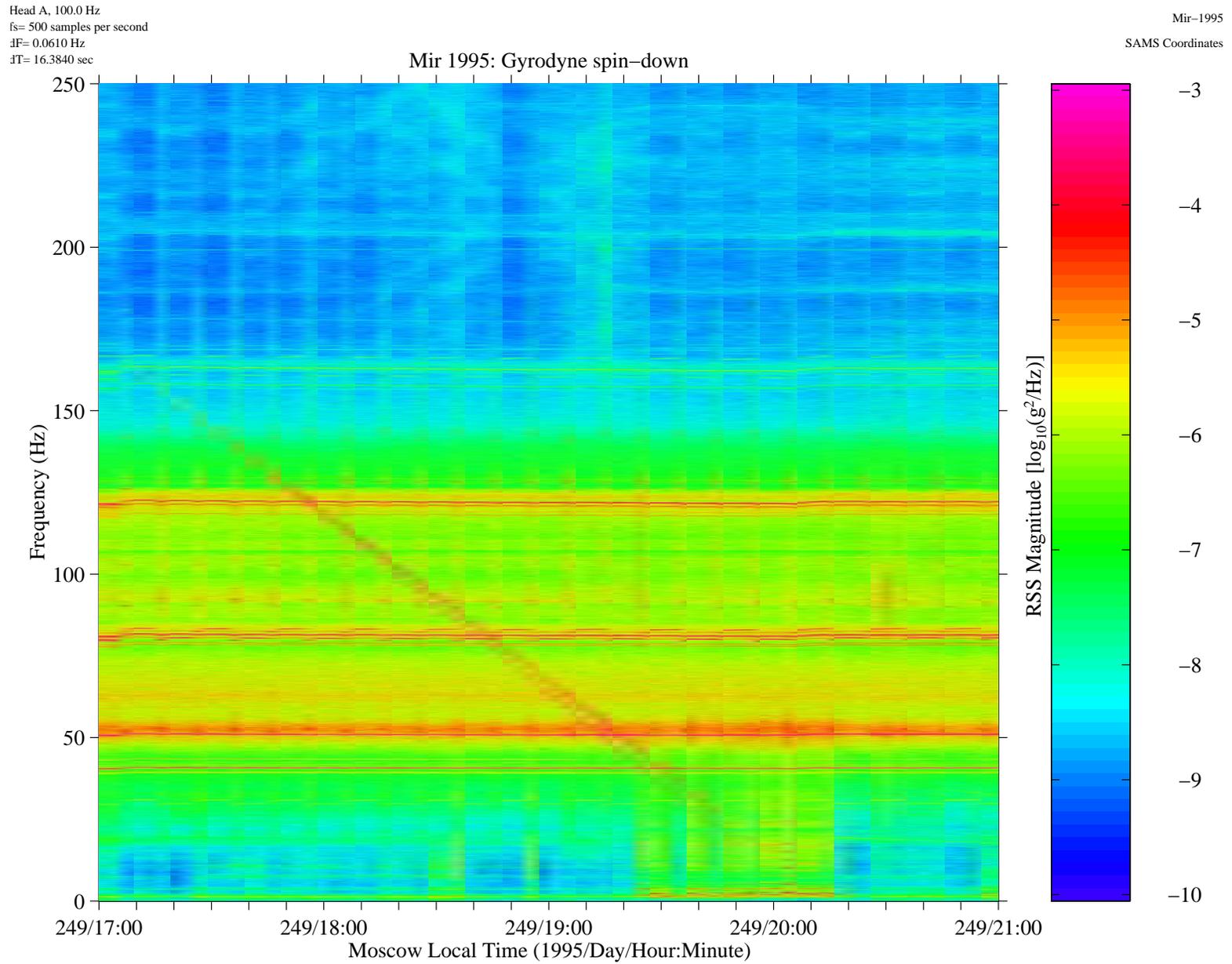
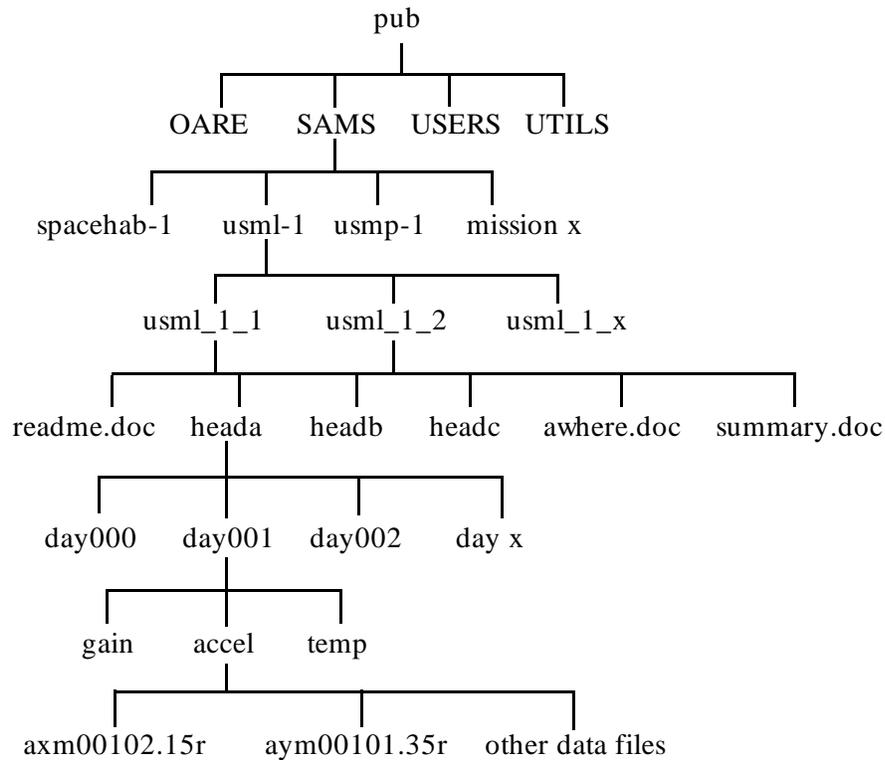


Figure 9. SAMS Head A data starting at MLT 249/17:00

Appendix A Accessing Acceleration Data via the Internet

SAMS data are available over the internet from the NASA LeRC file server beech.lerc.nasa.gov.

Files of SAMS data are organized in a tree-like structure. Data acquired from a mission are categorized based upon sensor head, mission day, and type of data. Data files are stored at the lowest level in the tree and the file name reflects the contents of the file. For example, the file named axm00102.15r contains data for sensor head A, the X-axis, the time base was Mission Elapsed Time, day 001, hour 02, 1 of 5 files for that hour, and it contains reduced data. The file readme.doc provides a comprehensive description and guide to the data.



SAMS Data File Structure

Also available from the file server are some data access tools for different computer platforms.

The NASA LeRC file server `beech.lerc.nasa.gov` can be accessed via anonymous file transfer protocol (ftp), as follows:

- a) Establish ftp connection to the beech file server.
- b) Login: anonymous
- c) Password: guest
- d) Change the directory to: pub
- e) List the files and directories in the pub directory. There are four directories at this level: OARE, SAMS, UTILS, and USERS.
- f) Change to the directory of choice.
- g) Change the directory to the mission of interest, for example: usml-2
- h) List files and directories for the specific mission chosen in previous step.
- i) Use the data file structure to find the files of interest.
- j) Enable binary transfer mode: bin.
- k) Transfer the data files of interest.

If you encounter difficulty in accessing the data using the file server, please send an electronic mail message to the internet address below. Please describe the nature of the difficulty and a description of the hardware and software you are using to access the file server.

`pims@lerc.nasa.gov`

Appendix B Acceleration Data Interval Average and RMS Time Histories

The Principal Investigator Microgravity Services (PIMS) group has further processed SAMS data from Mir Head A to produce the plots shown here. The data in this appendix does not contain the STS-74 docking. Two time history representations of the data are provided: ten second average and ten second root mean square (RMS) plots. These calculations are presented in two hour plots, with the corresponding average and RMS plots on one page. The ten-second interval average plots give an indication of net accelerations which last for a period of 10 seconds or more. Shorter duration, high amplitude accelerations may be seen with this type of plot, however their exact timing and magnitude cannot be extracted. The ten-second interval RMS plots give a measure of the oscillatory content in the acceleration data. Plots of this type may be used to identify times when oscillatory and/or transient deviations from the background acceleration levels occurred.

These average and RMS plots differ from similar plots produced in PIMS mission summary reports prior to January 1996. Previous plots tended to show an artificial spike when a gain change occurred within the SAMS unit. This artifact has been suppressed using gain change compensation routines.

Interval Average and Root Mean Square Calculations

These data were collected at 500 samples per second, and a 100 Hz low pass filter was applied to the data by the SAMS unit prior to digitization.

Prior to the production of the interval average and RMS plots, the data were demeaned. This was accomplished by demeaning individual sections with a nominal length of 10 minutes. The average plots were produced by calculating the average of ten second intervals of data for each axis.

$$\text{This operation is described as: } x_{\text{avg}_k} = \frac{1}{M} \sum_{i=1}^M x_{(k-1)M+i},$$

where x represents the x , y , or z axis data, M is the number of points analyzed in an interval, and k refers to the k th interval analyzed.

The resulting data streams (x_{avg} , y_{avg} , z_{avg}) are then combined by a vector-magnitude operation.

$$\text{This computation is expressed mathematically as: } \text{accel}_{\text{avg}_k} = \sqrt{x_{\text{avg}_k}^2 + y_{\text{avg}_k}^2 + z_{\text{avg}_k}^2}.$$

The RMS plots were produced by taking the root-mean-square of ten second intervals of data for each axis and forming a vector magnitude of the resulting data streams.

The interval RMS operation is expressed mathematically as: $x_{\text{RMS}_k} = \sqrt{\frac{1}{M} \sum_{i=1}^M (x_{(k-1)M+i})^2}$.

The same definitions apply for x, M, and k as in the interval average computation. The resulting data streams are combined by a vector-magnitude operation.

Appendix C SAMS Color Spectrograms

The SAMS data have been further processed to produce the plots shown here. The data in this appendix does not contain the STS-74 docking. Color spectrograms are used to show how the microgravity environment varies in intensity with respect to both the time and frequency domains. These spectrograms are provided as an overview of the frequency characteristics of the SAMS data during the mission. Each spectrogram is a composite of two-hour's worth of data. The time resolution used to compute the spectrograms seen here is 16.384 seconds. This corresponds to a frequency resolution of 0.0610 Hz.

The spectrograms contained herein differ from those spectrograms produced for PIMS mission summary reports prior to January 1996. Previous spectrograms utilized a colormap which had 8 colors. The new spectrograms contain 64 colors. Thus, the magnitude resolution (as represented by the color) shows a significant improvement. Care should be taken to not confuse the current colormap system with that used in reports prior to January 1996. For example, in previous spectrograms, yellow represented a higher magnitude than did red. The new colormap system is opposite when it comes to the yellow-red relation. The user is advised to refer to the colormap key located next to each spectrogram plot.

In order to produce the spectrogram image, Power Spectral Densities (PSDs) were computed for successive time intervals (the length of the interval is equal to the time resolution). For the PSD computation, a boxcar window was applied. In order to combine all three axes into a single plot to show an overall level, a Vector-Magnitude (VM) operation was performed.

$$\text{Stated mathematically: } VM = \sqrt{PSD_{x_k}^2 + PSD_{y_k}^2 + PSD_{z_k}^2} .$$

By imaging the base 10 logarithm (\log_{10}) magnitude as a color and stacking successive PSDs from left to right, variations of acceleration magnitude and frequency are shown as a function of time. Colors are assigned to discrete magnitude ranges, so that there are 64 colors assigned to the entire range of magnitudes shown. Data which fall outside of the maximum and minimum magnitude limits will be imaged as either the highest or lowest magnitude, depending on which side they have saturated. For this report, 0.21% of the total points lie below the lower limit, and 0.17% of the total points lie above the upper limit. If an area of interest seems to be saturated, care should be taken in that the actual values may lie above or below the color mapping shown on the plot.

Plot gaps (if any exist) are shown by either white or dark blue areas on the page. Care should be taken to not mistake a plot gap (represented by a dark blue vertical band) with a quiet period. If a plot gap exists for an entire plot (or series of successive plots), a comment is placed on the page to let the user know there is a gap in the data. These “no data available” comments will not show exact times for which the data are not available, but will only indicate missing plots.

Due to the nature of spectrograms, care should be taken to not merely read a color’s numeric value as being the “amount” of acceleration that is present at a given frequency. In order to get this type of information, the PSDs must be integrated between two frequencies. These frequencies (lower and upper) form the “band” of interest

$$g_{\text{RMS}} = \int_{f_1}^{f_2} \text{PSD} \cdot df .$$

The result of this integration is the g_{RMS} acceleration level in the $[f_{\text{lower}}, f_{\text{upper}}]$ band.

The PIMS group is able to provide this type of analysis on a per-request basis. To request this additional analysis, send an e-mail to pims@lerc.nasa.gov, or FAX a request to (216)433-8545.

Appendix D SAMS Time Histories (STS-74 Shuttle-Mir Docking)

The data represented here was obtained by the SAMS unit on Mir shortly before and for one day after the shuttle docked to Mir.

The plots here were processed in the same fashion as the Appendix B SAMS time history plots. The reader is referred to the Appendix B summary sheet for a summary of the procedures used to generate these plots.

Appendix E SAMS Color Spectrograms (STS-74 Shuttle-Mir Docking)

The data represented here was obtained by the SAMS unit on Mir shortly before and for one day after the shuttle docked to Mir.

The plots here were processed in the same fashion as the Appendix C SAMS color spectrograms. The reader is referred to the Appendix C summary sheet for a summary of the procedures used to generate these plots.

Appendix F User Comment Sheet

We would like you to give us some feedback so that we may improve the Mission Summary Reports. Please answer the following questions and give us your comments.

1. Do the Mission Summary Reports fulfill your requirements for acceleration and mission information? _____Yes _____No If not why not?

Comments:

2. Is there additional information which you feel should be included in the Mission Summary Reports? _____Yes _____No If so what is it?

Comments:

3. Is there information in these reports which you feel is not necessary or useful? _____Yes _____No If so, what is it?

Comments:

4. Do you have internet access via: (_____)ftp (_____)WWW (_____)gopher (_____)other? Have you already accessed SAMS data or information electronically? _____Yes _____No

Comments:

Completed by: Name: _____ Telephone _____
Address: _____ Facsimile _____
_____ E-mail addr _____

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